Field Testing of the Advanced Worker Protection System

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Abstract

The Advanced Worker Protection System (AWPS) is a revolutionary life support system technology that allows a suited worker to operate in a chemically hazardous or radiologically hot environment for up to two hours with minimal heat stress and minimal encumbrance from his life support equipment. The AWPS consists of three parts: a backpack with uses liquid air to supply breathing gas and cooling power; a liquid cooling garment (LCG) that circulates water which has been chilled in the process of vaporizing and warming the cryogen; and a Level B protective garment which accommodates the low profile of the backpack, permits greater mobility, and doesn't require tape closure. The AWPS backpack and LCG are compatible with commercially available Level A protective garments. The backpack which is the heart of the AWPS should be ready for NIOSH certification late in calendar 1996.

A one-hour duration AWPS prototype was demonstrated in September at the testing facilities of the International Union of Operating Engineers, IUOE, in Beckley, WV. User comments were captured on standard forms and analyzed. The purpose of the testing was four-fold:

- to provide user feedback on comfort, operation, encumbrance, and ease of use for input into the final stages of the design of the AWPS.
- to surface any design problems with the system's ruggedness and robustness in a realistic environment.
- to demonstrate the potential of the system for increasing user work times and decreasing recovery times for tasks which simulate actual decontamination activities.
- to shake down the new IUOE test facilities.

The activities began with a demonstration of filling the backpack with cryogen and

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donning and doffing of the backpack and garments [words about how that went]. This background activity was followed by a series of standard tasks established by IUOE: working in a vertically confined space: carrying a water pail, pushing a wheelbarrow, being decontaminated, driving a backhoe/bulldozer, and decontaminating heavy equipment.

[words about the results of the exercise.]

[words about the implications of the test results to DoE missions.]

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Introduction

The Advanced Worker Protection System (AWPS) is a revolutionary life support system technology that allows a suited worker to operate in a chemically hazardous or radiologically hot environment for up to two hours with minimal heat stress and minimal encumbrance from his life support equipment. The AWPS is a Self Contained Breathing Apparatus (SCBA) developed by Oceaneering Space Systems that uses low pressure liquid air rather than high pressure compressed air as in most other SCBAs. The AWPS consists of three parts: a backpack which uses liquid air to supply breathing gas and cooling power; a liquid cooling garment (LCG) that circulates water which has been chilled in the process of vaporizing and warming the cryogen; and a Level B protective garment which accommodates the low profile of the backpack and does not require tape closure.

In late 1995, the AWPS was chosen to be evaluated at the new International Environmental Technology Training Center being built by the International Union of Operating Engineers (IUOE). The IUOE is building this Technology Center on the grounds of the U.S. Mining Academy in Beaver, West Virginia. The mission of the IUOE and the Technology Training Center is to evaluate new technology that is planned for use by the Department of Energy (DOE). This gives the IUOE the opportunity to give user inputs to optimize new technologies for use in the DOE complex. Manufacturers of the technology benefit by receiving the user inputs prior to final design of the technology, and the equipment has the opportunity to experience a field environment.

Objectives of the AWPS Program

A worker in a chemical protective suit cannot work effectively for even the duration of a typical SCBA before being overcome by the heat build up in the suit. The suits worn are sealed up to prevent exposure to chemicals, but this also prevents evaporative cooling of heat generated by the wearer to evaporate away from the body. The build-up of heat and humidity within the suit are the primary causes of the onset of heat stress, which is the leading cause of job related injury. The objective of the AWPS program is to develop a breathing apparatus that will be certified to

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the National Institute of Occupational Safety and Health (NIOSH) the standard for open circuit self contained breathing apparatus. A breathing system cannot be used in the field without NIOSH certification. Once in use the breathing and cooling capabilities of a system such as the AWPS will eliminate the onset of heat stress

The objective of the IUOE Technology Evaluation was to gain user input and field experience to augment the development of the AWPS. Using the IUOE's standard protocol for given tasks, the AWPS would be integrated into the protocol in place of the standard compressed air SCBA typically used. The IUOEs protocols are similar to those typically used to qualify personnel for specific tasks. In this case, the protocols used field experienced personnel to assess the capabilities of a new technology.

Approach to the AWPS Development

The AWPS program has essentially followed the format originally scoped by OSS for the DOE development program. Phase I, completed in 1995, designed and developed a prototype of the AWPS concept in a lower fidelity than what would be eventually certified. This prototype was tested by Kansas State University, a third party laboratory, and the data and information gathered is now being used for the final design. Phase II of the program, which is ongoing, consists of the final design of the AWPS and units to be NIOSH certified. These units will be built and tested at DOE sites. The AWPS is expected to receive NIOSH certification in the Summer of 1997.

As the final AWPS design matured, the DOE decided to send it to the IUOE in order to:

- provide user feedback on comfort, operation, encumbrance, and ease of use for input into the final stages of the design of the AWPS.

- surface any design problems with the system's ruggedness and robustness in a realistic environment

- demonstrate the potential of the system for increasing user work times and decreasing recovery times for tasks which simulate actual decontamination activities.

- shake down and help evaluate the new IUOE test facilities.

The intent of this IUOE Technology Evaluation Program was to test units that were as close to the future certified units as possible. Two AWPS prototypes, with one hour duration, along with liquid cooling garments, splash suits, and a recharge station were taken to the IUOE's International Environmental Technology Training Center for evaluation in September, 1996.

AWPS History and Project Description

The concept of the AWPS evolved from a NASA development project to develop a self contained breathing and cooling system for use in the Johnson Space Center Weightless Environment Training Facility. This Neutral Buoyancy Primary Life Support System (NB PLSS) was developed to eliminate umbilicals used by the astronauts while training in the water environment. The system is

required to supply six hours of recirculating air and full body cooling. This was only the third Primary Life Support System ever to be "man-rated" by NASA.

Based on the success of the NB PLSS program, OSS was awarded a contract by the Department of Energy (DOE), in 1992, to develop the AWPS for use by Decontamination and Decommissioning personnel at the many DOE sites. The AWPS would be a pressure-demand system like standard SCBAs, rather than an semi-closed recirculating system such as the NB PLSS. The AWPS needed to be optimized for size, weight, and ruggedness of a commercial environment.

Phase I of the AWPS program included testing at Kansas State University in an environmentally controlled laboratory. KSU is an independent third party environmental and physiological testing facility. Several Manhattan Kansas Firefighters donned a Liquid Cooling Garment (LCG), a two hour duration backpack, and a liquid splash suit developed by OSS. The Firefighters would then complete a run/walk regime on a treadmill. The results demonstrated the potential payback of such a system to create a more efficient and safer work force.

In January 1996, even before AWPS design completion, the DOE decided to fund an evaluation at the IUOE facilities. It was understood that the design concept would be frozen in that state and prototypes for the evaluation program would be built with the technology at that time.

The evaluation program with the IUOE was being funded as part of the AWPS Phase II program. OSS built two AWPS One Hour units as well as LCGs, splash suits, and a recharge station to be evaluated at the IUOE's new Technology Training Center in Beckley, West Virginia. The evaluation sequence of this program was completed in September 1996.

Operating the AWPS

As a user the most important aspect to realize about the AWPS is that it supplies breathing air to the user just like any standard SCBA. The complimentary cooling aspect of the unit comes from the vaporization of the liquid air which is delivered to the user as breathing air. The liquid air exits the vacuum jacketed dewar and is vaporized through a primary heat exchanger using circulating water. The air is then circulated through a back-up heat exchanger, which can vaporize the air in the event of a cooling failure, and delivered to the user's mask at positive pressure. As the water circulates past the liquid air, via a specialized heat exchanger, it is cooled, and circulated back to the LCG which provides the worker with full body cooling. As the worker breaths, the water is cooled. The harder the work load, the heavier the breathing, the cooler the water becomes.

The operators with the IUOE were given instruction on filling the AWPS backpacks, donning the LCGs, donning the splash suits, and donning the backpacks. Donning and interfacing with the LCG required the most instruction because of its uniqueness as a whole. Using the backpack and splash suit was not much different from using standard SCBAs and protective suits.

As soon as the system was donned the users began to understand the benefits of the full body cooling supplied by the system. The operation of the system was able to be monitored using the

mask mounted display system. Because the AWPS uses a standard Scott Aviation mask, the user familiarization was made more simple.

The AWPS is "charged" (or filled) using a recharge station that can mate up with a standard SCBA cascade/fill system.

Results of the IUOE Evaluations

The evaluations took place from Wednesday September 18th, through Saturday September 21st. In all, twelve actual tests were conducted using each of the two AWPS packs, and covering seven of the IUOE Test Protocols. The protocols used in order were: Vertical Confined Space Entry, Water Pail Carry, Horizontal Confined Space Entry, Worker Decontamination, Wheel Barrel Push, Heavy Equipment Operation, and Heavy Equipment Decontamination. User comments were captured on standard forms and analyzed. The evaluations were very successful in fulfilling the objectives of the program.

The most valuable result of the evaluation was feedback from the actual users of the equipment that was provided on all aspects of the system. Comments on overall comfort of the garments and the backpack are important to creating a final product that is more acceptable to the end user. How the system operates, and how the user interfaces with the system is also important to the end user. Because the AWPS is a very new technology, and has slightly different interfaces than a standard SCBA, any encumbrances found by the user were regarded as important information.

Another important aspect of the evaluation process was to determine if the AWPS was ready for the "real world". The protocols completed during the evaluations were an excellent milestone in the determination of the systems ruggedness and ability to withstand normal field use. This was the area that OSS was most interested in gathering data. The equipment must be capable of handling the rigors of every day use. The equipment did not fail to supply the user air during any of the testing. Other components of the system will be optimized to better suit the environment.

The AWPS was also successful at demonstrating its capability to reduce the onset of heat stress, decrease the recovery times normally required of workers in these situations, and increase the work times of the worker. As stated above, workers were checked for pulse, respirations, blood pressure, and oxygen saturation in the blood, before the test, immediately after the test, and approximately twenty minutes following the test. The test subjects showed little to no signs of heat stress, and pulse rates recovered quickly after doffing the respirator.

The evaluations also sought to determine how well the evaluation process worked both for the IUOE and for OSS. We as OSS feel that this was an outstanding opportunity to evaluate our technology in a field environment. When the equipment did experience symptomatic problems, the OSS personnel on site were allowed to diagnose the problems so that the equipment could be properly optimized at a later date. Because of this type of cooperation throughout the evaluation process, we will be able to build a better product for the DOE.

The backpacks never failed to supply the user air throughout the testing in any environment and in any orientation. During several of the tests the packs electronics turned the pump off when it

sensed what it thought was a problem in the system. The reason was a constricted water line in the LCG that was created by the body harness warn for Confined Space Entry work. This was discovered during the first Vertical Confined Space Entry test. The water circulating pump shutdown approximately fifteen minutes into the test protocol. Because the user was still receiving breathing air the protocol was completed, and the user remarked that he remained cool throughout the exercise. The remaining three tests involving Confined Space Entry proved to highlight the same problem with the system.

While performing some of the other tests the pump appeared to be laboring while the worker performed certain tasks that in some way were constricting the flow of water. This information is invaluable in order to make the system more rugged for field use. Information on user comfort, and any encumbrance of the system was also gathered during these same tasks. All comments on the backpack itself were complimentary in the way it fit, how it felt, and it's weight. The AWPS One Hour system has a profile off the users back of less than five inches. This allowed the subjects to enter the confined space tube without removing the backpack. Ascending the catwalk on the vertical tower was also made easier by this low profile. Comments on the LCGs were also complimentary. The water hose interfaces between the backpack and the LCG were said to be annoying, and could be an encumbrance because of the way they were looped out of the splash suit. The splash suits obtained many comments on the fit and feel, the lack of visibility of the hood, and the ambient noise created by the moving of the material. This information can now be incorporated into the Phase II AWPS design.

Other user related information that came from the testing was the ability of the worker to "recover" after a protocol was performed. Pulse rate, breathing rate, blood pressure, and oxygen saturation measurements were taken prior to each test, immediately after each test, and five minutes after each test to determine the worker's recovery rate. After each test the test subject/ worker was able to recover and be prepared for another test within twenty minutes.

The remaining test protocols were completed and more user inputs and operational type refinements were generated. The information gathered by OSS and the IUOE will be used for the Phase II design of the AWPS which is on going.

We found that while the IUOE was evaluating the AWPS, the AWPS was also evaluating the processes of the IUOE and the facilities. We found the IUOE personnel as well as the evaluators to be extremely knowledgeable and helpful in the area of Personal Protective Equipment. At the time of this writing, the IUOE data and the OSS data have not been completely compiled. OSS looks forward to receiving and incorporating the information gathered into on-going activities.

Benefits

The primary application of this technology is to the worker in the Decontamination and Decommissioning of the many DOE sites. The IUOE field testing verified that the AWPS relieves the worker of the symptoms of heat stress and allows the worker to be more efficient and concentrate more on the task at hand. One of the heavy equipment operators at the IUOE technology evaluations while wearing the AWPS on a backhoe actually said "because I was not worried about

getting hot and stressed in the suit, I was able to concentrate better on operating the equipment and doing my job."

Future Activities

Phase II of the AWPS Program will conclude with the demonstration of two hour duration NIOSH certified AWPS units at one of the DOE sites. Once this is completed the AWPS will be ready for the commercial market. OSS has been invited to several other demonstrations and evaluations at other DOE sites. The information gathered from these tests is invaluable to the development of a system such as the AWPS. As NIOSH certification approaches for the AWPS more and more user inputs will be incorporated. Once the AWPS is NIOSH certified, it will be put into more demanding field evaluations. The information gathered at these evaluations will be used for the next generation of NIOSH certified Advanced Worker Protection Systems.

Contract Information
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